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Effects of asphalt emulsion on properties of fresh cement emulsified asphalt mortar

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HIGHLIGHTS

- Effects on two types of emulsified asphalt were investigated.
- Two types of cement emulsified asphalt mortar were included.
- Various properties of fresh cement emulsified asphalt mortar were evaluated.
- Factors affecting fresh cement emulsified asphalt mortar were explored.

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ABSTRACT

This study evaluates the effects of two types of asphalt emulsion, anionic and cationic emulsions, on the properties of two types of cement emulsified asphalt mortar (CEAM), low-modulus CEAM and high-modulus CEAM, at varying asphalt to cement ratios (A/C). The study focused on the effects of emulsion on the properties of fresh CEAM mixes, including workability, cement hydration, dynamic shear modulus, and phase angle. The workability was evaluated using the flow table test. The cement hydration and dynamic shear rheometer (DSR) tests were performed to investigate the cement hydration development and viscoelastic properties of CEAM mixes. In addition, the uniaxial compressive strength was tested to examine the effects on the properties of hardened CEAM mixes. The laboratory test results show that the workability evidently decreased with the increase in A/C and the adoption of cationic asphalt emulsion. Increase in A/C ratio lowered the cement hydration rate in CEAM. Cationic asphalt emulsion and higher cement content made CEAM stiffer as it exhibited higher complex shear modulus. There was a significant reduction in compressive strength of the mortars with the increase in A/C ratio. Cationic asphalt emulsion was desirable for high-modulus CEAM because it could give CEAM a higher compressive strength than anionic asphalt emulsion at different ages.

1. Introduction

To date, ballastless slab track is widely used in high-speed railways in many countries such as Japan, Germany, France and China [1], due to low maintenance, long service life, and reduced structure height [2]. The cement emulsified asphalt mortar (CEAM) is a key component in the structure of ballastless slab track and serves as the leveling and damping material between rigid slab and the concrete base [3]. Currently, there are two types of CEAM: Type I (low-modulus CEAM) that is applied to unit slab track and Type II (high-modulus CEAM) that is applied to continuous slab track [4,5]. CAEM mainly consists of cement matrix, asphalt emulsion, fine aggregate, and a variety of admixtures [6]. However, cement and asphalt emulsion are the two primary binders, which is quite different from the situation where asphalt emulsion is used just as a modifier in cement mortar [7]. In addition, due to the presence of asphalt in its structure, CAEM exhibits quite different properties from cement mortar [8]. Asphalt emulsion types and A/C ratios play a significant role in CEAM quality [9].

Many research efforts have been made in recent years to investigate the A/C effect on properties of CEAM. Earlier researchers focused on the beneficial effects of Portland cement as an additive to asphalt emulsion in cold mixtures [10–12]. Later, Oruc et al. [13] studied effect of cement on mechanical properties of cement emulsified asphalt mixtures and showed that mechanical properties of

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CEAM are significantly improved by cement. Kong et al. [14] investigated the compressive strength developing process and the microstructure of cement–asphalt mortar (CA mortar) and found that the fluidity of CA mortar has a great influence on its strength. Liu et al. [15] studied static and dynamic mechanical properties of cement–asphalt composites with various contents of asphalt and obtained uniaxial compressive stress–strain curves of cement–asphalt mortars at different A/C ratios and different testing temperatures ranging from −40 to 80 °C. Wang et al. [16,17] reported that binder contents can influence the internal air void numbers and their distributions as well as such properties as indirect tensile strength and dry shrinkage of cement asphalt emulsion mixtures.

The interaction between cement and asphalt emulsion and their effect on the properties of CAEM were studied in recent years from physico-chemistry point of view to explain the mechanisms. For example, Hu et al. [18] adopted a laser particle size analyser to characterize the particle size variation of emulsion and found that the workable time of the mortar is controlled by the early age interaction between cement and asphalt emulsion. Pouliot et al. [19] studied the hydration process, the microstructure, and the mechanical properties of cement asphalt emulsion mortars. Wang et al. [20,21] investigated compatibility between cement and asphalt emulsion types and studied the effect of pH value, Ca^{2+} concentration and water loss on emulsion stability. Lu et al. [22] investigated the effects and reaction mechanisms associated with sodium carboxymethylcellulose (CMC-Na) in cement–asphalt mastic to improve and restrain settlement and stratification of the mortar. Zhang et al. [23] discussed the effects of asphalt emulsion types, temperature, and time on the rheological properties of fresh cement asphalt paste at temperatures of 0, 20 and 40 °C. Liu et al. [24] studied the effects of water, time and feeding sequence on the mortar fluidity and characterized flow ability of the mortar by fluidity. Tan et al. [25] studied the retarding effect of different emulsifiers on cement hydration by measurement of cement setting time, hydration heat and X-ray diffraction.

However, few researches have been carried out to explore suitable asphalt emulsion types to improve the properties of CEAM such as cement hydration heat, viscoelasticity and compressive strength. Therefore in this study, two types of asphalt emulsions were used to produce two types of CEAM at different A/C ratios. The objective of this study was to investigate the effects of asphalt emulsion type on the properties of CEAM, including workability and uniaxial compressive strength. In addition, complex shear modulus and cement hydration heat of CEAM paste were also carried out to explain the interaction mechanism between asphalt emulsion and cement.

2. Materials and experiments

2.1. Materials

All mix designs were made using standard Type III Portland cement for its high early strength to help counteract the slow setting time and retarding effect of asphalt emulsions. Two types of asphalt emulsions, anionic and cationic, with 60% residue were used for Type I and Type II CEAM. Tap water, medium range water reducer (MRWR) and dried natural sand were used as ingredients for sample preparation.

2.2. Experiment program

2.2.1. Preparation of CEAM

The mix designs used for Types I and II CEAM are presented in Table 1. The A/C ratio was defined as the ratio of the mass of asphalt residue to cement mass. Six A/C ratios were used and they are 0.13, 0.35, 0.57 for Type II and 0.72, 0.94, 1.16 for Type I. For CEAM made with anionic emulsion, the A/C was denoted by A/C-a, such as 0.13-a and 0.35-a. For CEAM with cationic emulsion, the A/C was denoted by A/C-c, such as 0.13-c and 0.35-c. The amount of water in asphalt emulsion was counted into the calculation of water dosage. A mixer with paddles was used to mix CEAM mixtures at ambient temperature. During mixing, water reducing admixture and half of water were first added into the asphalt emulsion in the bowel of the mixer and natural sand was then added. Cement and the other half of water were added last. The mixing duration was three minutes.

Table 1
Proportions of CEAM (g).

A/C	Cement	Asphalt emulsion	Water	Natural sand	MRWR	Type of CEAM
0.13	550	115	256	923	6.80	II
0.35	550	313	177	804	6.80	
0.57	550	511	98	685	6.80	
0.72	300	363	85	649	3.71	I
0.94	300	471	42	584	3.71	
1.16	300	579	0	518	3.71	

2.2.2. Workability test

The workability of fresh CEAM is measured by the flow of the mortar. In accordance with ASTM C1437 [26], a standard flow table and a flow mold with a conical shape were used for the flow test of fresh CEAM at temperature 20 °C. After being mixed, the fresh CEAM sample was placed on the flow table and dropped 25 times within 15 s. As the sample was dropped, it spread out on the flow table. The initial and the final diameters of the mortar sample were used to calculate the flow. Flow was defined as the increase in diameter divided by the original diameter multiplied by 100.

2.2.3. Heat of hydration test

In order to explain how the asphalt emulsion affects cement hydration, the heat of hydration for the CEAM pastes was measured using an I-Cal 8000 isothermal calorimeter. After the temperature balance of the instrument was reached, the

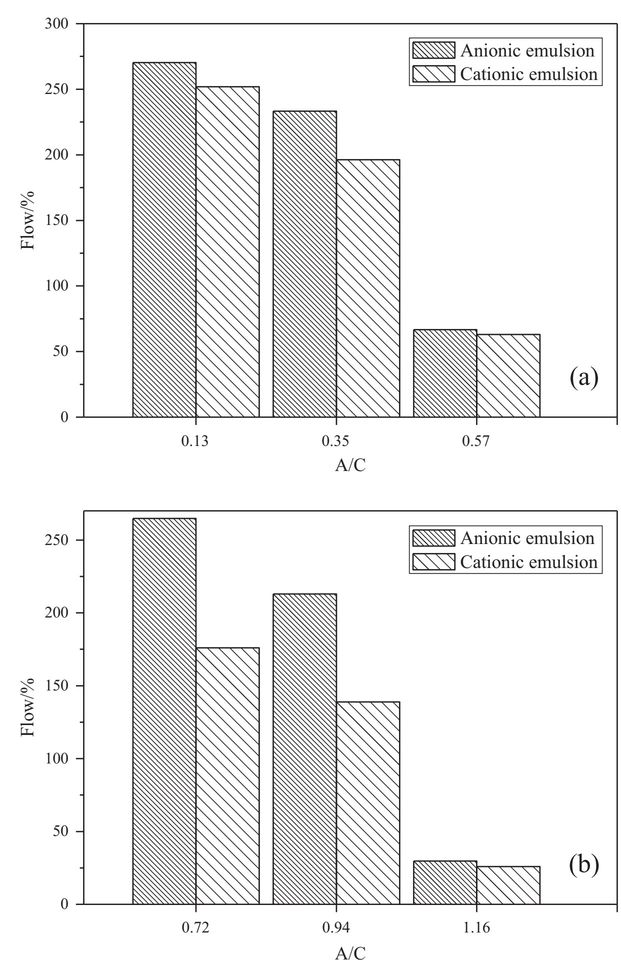

Fig. 1. Workability of CEAM: (a) Type II and (b) Type I.